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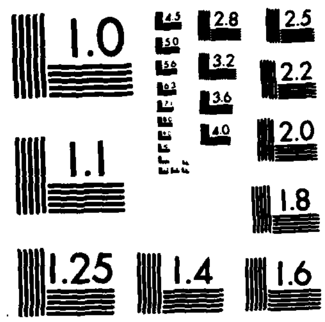

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ALPHATECH, INC.

ASWC'S (ANTISUBMARINE WARFARE CENTER'S)

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TR-162

PROJECT STATUS REPORT

Contract Number N00014-81-C-0740

Work Unit No. NR 460-001

24 May 1983

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The emphasis of the research to date is the development and coding of a mathematical model of the ASWC's tactical decisionmaking process. It is a cognitive simulation in that it not only tries to mimic human response, but tries to solve problems in a humanoid way. The simulation is comprised of three main components. They are: ~~(1)~~ an environmental driver, ~~(2)~~ a situation assessor, and ~~(3)~~ a resource manager. The latter two components represent the ASWC's two primary activities. These correspond to the Hypothesis (H) and Option (O) functions of the SHOR paradigm.

The ASWC model and environmental driver are diagrammed ~~in Figure 1~~. The simulation's input data, environmental driver, situation assessor, resource manager, and output data are described ~~below~~.

Input Data

The input data are partitioned into two categories: technical and cognitive style input data.

The technical input data are as follows.

1. BG composition. That is, the number and types of carriers, destroyers, cruisers, frigates, fixed-wing aircraft, ASW helicopters, and direct support attack submarines.

2. BG speed of advance and heading.

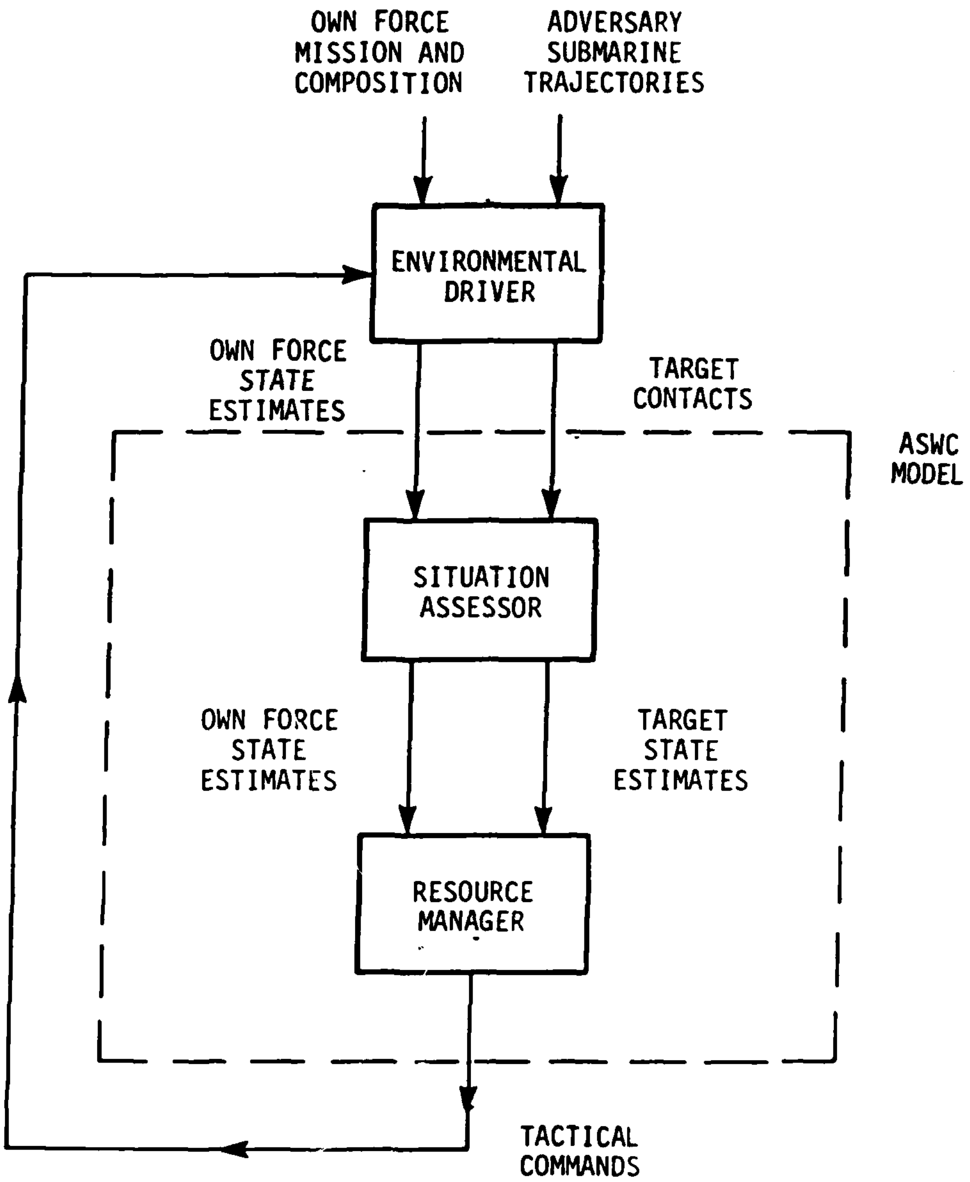

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Figure 1. ASWC model and environmental driver.

3. BG screen configuration: platform stationing and search patrol patterns.

4. Platform operational and acoustic capabilities and limitations.

5. Likelihood functions for passive sonar sensor probability of detection and probability of false alarm.

6. Acoustic and environmental conditions.

7. Adversary submarine trajectories.

8. Termination conditions.

The cognitive style of the ASWC is described by four characteristics. They are:

1. The reflectivity-impulsivity of the commander. This characteristic determines the time required for the commander to make a tactical decision.

2. The field dependence-independence of a commander. This characteristic determines the commander's ability to derive tracks from multiple contacts, typically from different platforms at different times.

3. The commander's ability to cope with stress. This determine the commander's decisionmaking efficacy, or degree of optimality. The stress is a function of his resource availability and perceived threat facing the BG.

4. The commander's probabilistic inference bias. This determines the power that the likelihood function is raised to in the Bayes theorem. An unbiased probabilistic information processor would have this exponent equal to one.

Environmental Driver

Given the aforementioned input data and tactical commands issued by the ASWC, the environmental driver updates the BG's states and generates target contact data. The states of the BG are as follows. The spatial location [Nm,Nm], velocity [Nm/hour], heading [degrees], sonar sensing status, and ASW command status are the states of the surface and the subsurface platforms.

The additional states for the helicopters and the fixed-wing aircraft are the time-since-launch [hours], time-since-return [hours], and destination [Nm,Nm]. The states of the sonobuoys are their spatial locations [Nm,Nm], and their time-since-deployment [hours].

Target contacts are comprised of the sensor's location at time of contact [Nm,Nm], the sensor type, the contact bearing [degrees], and the contact time [hours]. A contact is generated when the adversary submarine is within the passive sonar range of the sensor (direct path, and possibly one or two convergence zones, dependent on the input environmental and acoustic conditions). The contact bearing is subject to error and is therefore corrupted by Gaussian noise.

Situation Assessor

The purpose of the situation assessor is to transform raw contact, bearing only, data into target tracks. By exploiting the fact that surface sensors can only hear submarines in narrow annuli about the ship (direct path and convergence zones), it is possible to make inferences about the contact's range for coherent data associations. For example, since the average distance between annuli is roughly thirty miles, it is possible to exclude associations between existing tracks and contacts by computing the target's velocity for all possible ranges. Certain feasible ranges can be omitted because the velocity computed to make an association with a track is too great.

The likelihood of the track's being a true track is measured by the consistency of the estimated target heading. That is, for each data association a new target heading is computed. The consistency is determined by calculating the root mean square error of the target headings. Unlikely tracks are pruned on the basis of inconsistent headings or too few data associations.

The outputs of the situation assessor are the track state estimates: inertial coordinates [Nm,Nm], velocity [Nm/hour], and heading [degrees].

Resource Manager

After an extensive ASW literature review and interviews with seasoned ASW personnel, it has been concluded that the resource management activity can be justifiably conceptualized as a set of conditional rules of engagement. The conditions are: (1) after an initial submarine contact, (2) after a redection, (3) after no redetection, (4) after a localization, and (5) after a prosecution.

Within each of these rules are a series of functions that are carried out by the ASWC. Some are entirely dictated by doctrine and some are knowledge-based and subject to individual interpretation. For each knowledge-based function, mathematical representations that are sensitive to some or all of the cognitive style characteristics are constructed. For example, after an initial contact from a surface escort the ASWC must decide which air asset to send to localize the target. His objectives are to minimize the time-late (transit time), or area of uncertainty, and maximize the asset's time on station. An impulsive commander would be apt to send an already airborne asset and address the asset's staying power in the future, i.e., extremize the time-late objective. Conversely, a reflective commander would try to satisfy both objectives.

The commander's ability to manage stress is represented as the optimality of the decision rule employed to specify the action in some functions. Using the above example, the impulsive commander under great stress would probably select any of the available airborne assets without regard to its time late.

The outputs of the resource manager are commands to platforms; surface platforms are commanded to destinations. Airborne assets are commanded to destinations and are commanded to employ sonobuoy localization patterns. It is assumed that the ASWC can not command the direct support submarines.

Output Data

The model outputs the time series of platform commands issued by the ASWC and a number of measures of effectiveness. They are the percentage of enemy submarines obtaining their weapons' release range, the percentage of initial contacts localized, the average time between initial contact and prosecution, the deviation from the BG's position and intended movement (PIM), and the airborne asset utilization statistics.

Task Outline

The schedule of the remaining project tasks is diagrammed in Figure 2. We shall:

1. Encode direct support submarine (DSS) into battle group configuration. DSS to generate long range sonar contacts with time delay, bearing error, and range ambiguity.

2. Encode barrier patrol searches for surface and subsurface escorts.

3. Develop heuristic algorithm that forges submarine tracks from imperfect bearing only measurements from distributed sensors. Algorithm shall also specify likelihood of a track being an actual track.

4. Encode tracking algorithm.

5. Identify and develop conditional rules of engagement for the ASWC. Conditions are: after an initial submarine contact, after a redetection, after no redetection, after a localization, and after a prosecution.

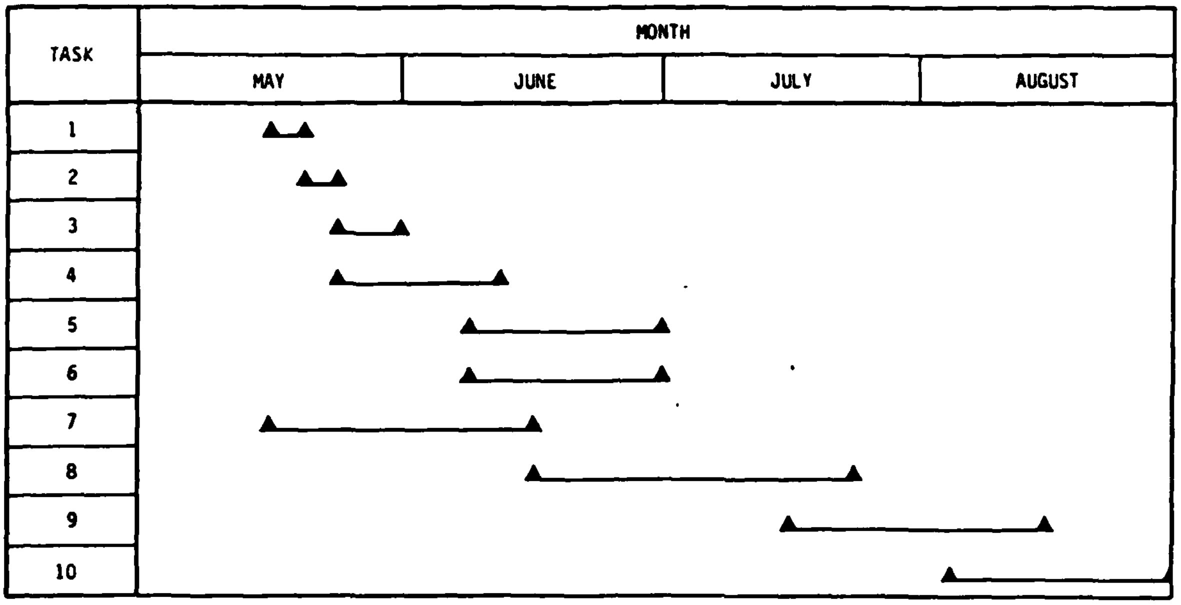

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Figure 2. Project schedule.

6. Identify, within specified rules of engagement, knowledge-based and condition-action functions.

7. Identify the cognitive considerations that affect knowledge-based decisionmaking. Delineate small subset of considerations that can be embedded into the model structure, i.e., can be quantified.

8. Encode rules of engagement. Develop prescriptive decision-making algorithms for knowledge-based functions that are not sensitive to the cognitive considerations encoded.

9. Exercise the model to assess its validity.

10. Write the final report.